RADIOTRONICS

AMALGAMATED WIRELESS VALVE CO. PTY. LTD.

BOX No. 2516 BB G.P.O., SYDNEY

TECHNICAL BULLETIN No. 83 **28th JANUARY, 1938**

In this issue:—

RESISTANCE-COUPLED PUSH PULL

Application of Series Inverse Feedback

The method of phase splitting used in many recent Radiotron circuits, employing equal resistors in the plate and cathode circuits of a triode, has proved to be extremely satisfactory both in laboratory tests and in service. This method is excellent in its application to triode power valves such as Radiotron 2A3's (Circuits A115 and A120) and may also be used with beam tetrodes or with pentodes. Its applications are limited, however, since no method has been discovered whereby it can be used with negative (inverse) feedback without the use of a transformer. This disadvantage is a serious one, and many efforts have been made to discover a circuit which can be used in such a way.

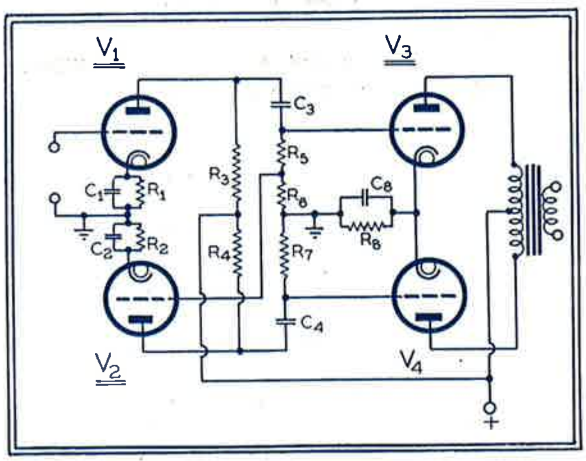

Fig. 1.

One method which has been used very widely with resistance coupled push-pull amplification is shown in Fig. 1. In this circuit valve V_1 excites the grid of the output valve V_3. Out-of-phase voltage is taken from the plate circuit of V_1 by means of the voltage divider R_5, R_6 and applied to the grid of V_2 and thence to V_4. In order to obtain identical grid voltages on V_3 and V_4 it is necessary to adjust the voltage divider R_5, R_6 so that the effective gain from the plate of V_1 to the grid of V_4 is unity.

This circuit has a very serious defect in that the adjustment of the divider R_5, R_6 should be made for each individual valve, and may also need to be re-set during the life of the valve. Its advantages are nevertheless sufficiently pronounced to encourage its use in spite of these disadvantages. This circuit does not appear to bear any particular title, although it is frequently called "the paraphase circuit"—this being an erroneous title, as will be shown.

Old Circuit Re-applied

A search has revealed a modified form of this circuit with most interesting possibilities. This circuit, under the title "Paraphase," was used in the "Science Museum Receiver" in London, as described by Denman and Brereton(1) in 1930. Whether the designers of this receiver fully appreciated its operation is not certain, but the undoubted fact is, that they adopted an arrangement with outstandingly good performance. In the years since then it seems that this

RESISTANCE COUPLED PUSH PULL (Continued)

arrangement has failed to excite any interest, probably on account of the very slight difference between the two circuits and the confusion in applying the name "Paraphase" to both.

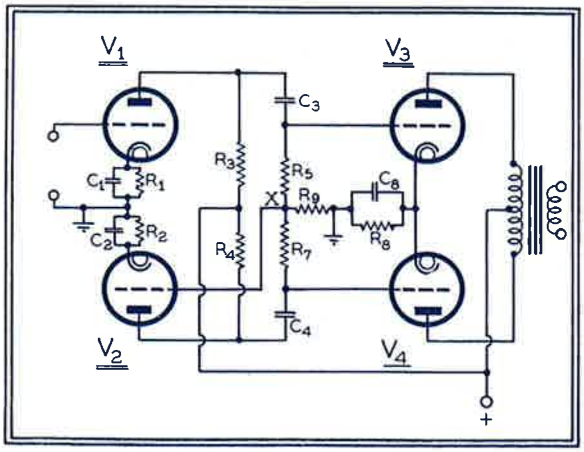

Fig. 2.

The principle of this true Paraphase circuit is shown in Fig. 2, and the only differences between it and Fig. 1 are in the omission of resistor R_6 and the addition of resistor R_9. In order to visualise the operation of this circuit consider firstly the situation with V_2 removed. Resistors R_5 and R_9 in series form the load on valve V_1, and the voltage at the point X will be in proportion to the voltage of the grid of V_3. When V_2 is added, the voltage initially at point X will cause an opposite voltage to be applied to resistors R_7 and R_9. If resistor R_7 is slightly greater than R_5 it will be found that the point X is nearly at earth potential. If the amplification of V_2 is high, then R_7 may be equal to R_5 and point X still nearly at earth potential. The point X may therefore be regarded as "floating," and the complete circuit may for convenience be called the "Floating Paraphase Circuit."

Floating Paraphase Circuit

It will be seen that as the amplification of V_2 varies, so there will be a compensating effect tending to produce equal voltages on the grids of V_3 and V_4. If V_2 is a pentode valve, such as Radiotron 6J7G or 1K5G, it is possible to make R_7 equal to R_5, while keeping the balance between V_3 and V_4 within about 3%. If it is desired to obtain exact balance this may be accomplished by increasing the resistance of R_7. With class A operation it is quite satisfactory to use R_5 and R_7 of the same nominal resistance and with 5% tolerance on each.

A brief technical analysis which may be used as the basis of design is given in the Appendix. Without the use of mathematics it is very difficult to describe accurately the operation of the circuit, and an examination of this simple mathematical treatment will be necessary for a proper understanding.

If high gain pentodes are used in positions V_1 and V_2, it is quite practicable to apply Series Inverse Feedback in the normal manner to both valves. By this means it is possible to use pentode or beam tetrode valves in positions V_3 and V_4 and yet to obtain good fidelity. There is no point in applying negative (or inverse) feedback when V_3 and V_4 are triodes, and, in fact, such would be extremely difficult owing to the very large signal voltages required, which would tend seriously to overload V_1 and V_2.

This Floating Paraphase Circuit is capable of being applied to all types of pentodes or beam tetrodes. A circuit using the new Radiotron 6V6G valves is given in this issue, but the same principle may be used with 6L6G, 6F6G, or other types of valves. It is hoped to describe at a later date a circuit showing a further application to battery valves. Since no cathode is operated at a high potential above earth it is possible to use directly heated valves in all stages. V_1 and V_2 may be Radiotron types 1K5G (1K4) or 1K7G (1K6), while V_3 and V_4 may be 1F5G's (1F4's), or if desired, V_3 and V_4 may both be replaced by a single 1E7G.

Although the Floating Paraphase Circuit may be very widely adopted with applications requiring negative (or inverse) feedback, it does not appear to offer any advantages over the method of phase splitting used with triode power valves in Radiotron Circuits A115 and A120. Each arrangement appears to have a sphere of application within which it is the most suitable method.

(1) R. P. G. Denman and A. S. Brereton, *Wireless World*, July 30th, 1930, p. 96 et. seq.

APPENDIX

Simple Mathematical Treatment

Let e_1 be the voltage developed in the plate circuit of V_1.

Let e_2 be the voltage developed in the plate circuit of V_2.

Then neglecting voltage drop in coupling condensers, we may reduce the circuit to an equivalent diagram as shown.

By Kirchhoff's laws we have :—

$$e_1 = i_1 R_1 + e_3 \quad \ldots\ldots (1)$$
$$e_2 = i_2 R_2 + e_3 \quad \ldots\ldots (2)$$
$$e_3 = i_3 R_3 = (i_1 + i_2) R_3 \quad \ldots\ldots (3)$$

From (1), $i_1 = \dfrac{e_1 - e_3}{R_1} \quad \ldots\ldots (4)$

From (2), $i_2 = \dfrac{e_2 - e_3}{R_2} \quad \ldots\ldots (5)$

From (3),

$$\frac{e_3}{R_3} = i_1 + i_2$$
$$= \frac{e_1 - e_3}{R_1} + \frac{e_2 - e_3}{R_2}, \text{ from (4) \& (5).}$$

i.e. $\dfrac{e_3}{R_3} + \dfrac{e_3}{R_1} + \dfrac{e_3}{R_2} = \dfrac{e_1}{R_1} + \dfrac{e_2}{R_2}$,

i.e., $e_3\left(\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}\right) = \dfrac{e_1}{R_1} + \dfrac{e_2}{R_2} \quad \ldots (6)$

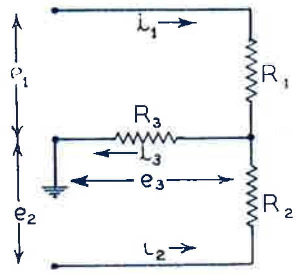

Fig. 3.

Now the voltage e_3 is applied between the grid of the phase inverting valve (V_2 in Fig. 2) and earth and a voltage of $m \cdot e_3$ will be generated in its plate circuit if m is the stage gain.

That is to say :—

$$\frac{e_2}{e_3} = -m \text{ or } e_3 = -\frac{e_2}{m} \quad \ldots\ldots (7)$$

the negative sign indicating the change of phase.

Substituting this in (6) we have :—

$$-\frac{e_2}{m}\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) = \frac{e_1}{R_1} + \frac{e_2}{R_2}$$
$$\therefore -\frac{e_2}{m}\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{m}{R_2} + \frac{1}{R_3}\right) = \frac{e_1}{R_1}$$

Multiplying both sides by $\dfrac{R_1}{e_2}$, we have :—

$$-\frac{e_1}{e_2} = \frac{R_1}{m}\left[\frac{1}{R_1} + \frac{1}{R_2}(m+1) + \frac{1}{R_3}\right]$$
$$\therefore -\frac{e_1}{e_2} = \frac{1}{m}\left[1 + \frac{R_1}{R_2}(m+1) + \frac{R_1}{R_3}\right] \quad (8)$$
$$= \frac{R_1}{R_2} + \frac{1}{m}\left(1 + \frac{R_1}{R_2} + \frac{R_1}{R_3}\right) \quad (9)$$

This expression enables the degree of balance to be calculated since e_1 and e_2 are the voltages applied to the grids of the two output valves. It will be seen from expression (9) that when m is great the balance depends mostly on $\dfrac{R_1}{R_2}$.

In order to illustrate the application of expression (8) we may consider the circuit of the 8·5 watt 6V6G amplifier (A130). In this circuit :—

$R_1 = 0{\cdot}2$ megohm,
$R_2 = 0{\cdot}2$ megohm,
$R_3 = 0{\cdot}3$ megohm
and $m = 80$.

Applying these values to expression (8) we have :—

$$-\frac{e_1}{e_2} = \frac{1}{80}\left[1 + \frac{0{\cdot}2}{0{\cdot}2}(80+1) + \frac{0{\cdot}2}{0{\cdot}3}\right]$$
$$= \frac{1}{80}\left[1 + 81 + 0{\cdot}6\right]$$
$$= \frac{82{\cdot}6}{80}.$$

This is equivalent to an unbalance of slightly over 3% which may be neglected completely. If it is desired to secure perfect balance, resistances R_1 and R_2 in Fig. 3 should be selected so as to be in the ratio 200,000 to 206,000, R_2 being the greater.

NEW RADIOTRON RELEASE

Radiotron 1612

Non-Microphonic Amplifier

As announced in Radiotronics 82, the Radiotron 1612 is a pentagrid amplifier similar to Radiotron 6L7. As with the 6L7 the new 1612 is an all-metal type and has similar dimensions and base to the 6L7. The inter-electrode capacitances and electrical characteristics are in all respects identical to the 6L7. Although the 1612 may be used in any application in which a valve of the 6L7 type is required to be free from microphonics and from noise, its particular application is as a volume control valve in audio circuits. It may be used for volume expansion, or for volume compression, either manual or automatic.

In normal usage the audio frequency signal voltage is applied to grid No. 3 and the controlling voltage is applied to grid No. 1. Reference should be made to the data on Radiotron 6L7 for characteristics and curves.

8.5 WATT 6V6G AMPLIFIER

Inverse Feedback with Resistance-Coupling

The method of phase splitting described earlier in this issue as "The Floating Paraphase Circuit" enables Series Inverse Feedback to be applied to a push-pull amplifier and thereby provides good fidelity coupled with economy. One of the most interesting applications of this circuit is in connection with class AB1 operation of Radiotron 6V6G's, whereby an output of 8.5 watts may be obtained. The circuit is shown in the diagram as Radiotron circuit No. A130 and it will be seen that the amplifier itself consists of four valves in all. The first stage is Radiotron 6J7G (6C6), the phase splitting stage is another 6J7G, while the output stage consists of two type 6V6G's operated under class AB1 conditions with 250 volts between plates and cathodes. Radiotron 5V4G (83V) is used as a rectifier in order to obtain high D.C. voltage from a 385 volt transformer and through its use it is practicable to employ standard electrolytic condensers without any risk of failure. If a rectifier valve having higher impedance than the 5V4G is preferred, it will be necessary not only to increase the transformer voltage, but also to watch carefully the peak voltage on the first electrolytic condenser. Provision has been made for one or two field coils each of 750 ohms and excited by 11 watts. If only one field is required the other may be replaced by a suitable choke together with a series resistance to make up a total resistance in this section of 750 ohms.

The input to the amplifier as described, with the degree of inverse feedback shown in the circuit, is 0.318 volt R.M.S. (0.45 volt peak). If it is required to operate from a low level it is suggested that one Radiotron type 1603 be used as a resistance coupled pentode pre-amplifier. With the constants shown in the circuit, it is possible to operate extremely satisfactorily from a crystal microphone into the pre-amplifier grid and from a crystal or sensitive electro-magnetic type of pick-up directly into the 6J7G grid. An interesting point arises in connection with the application of a crystal microphone since the microphone is generally required to operate into a load of 5 megohms, while the maximum resistance in the grid circuit of a valve used as a resistance coupled pentode pre-amplifier should not exceed 2 megohms. This difficulty has been overcome in the circuit diagram by placing a load of 5 megohms across the crystal microphone and by tapping down to a suitable point on this load so that the grid circuit resistance shall not exceed 2 megohms. By this means there will be a loss of 60% in voltage (8 dB), but this is not serious since the gain of Radiotron 1603 is sufficiently high to provide full output from

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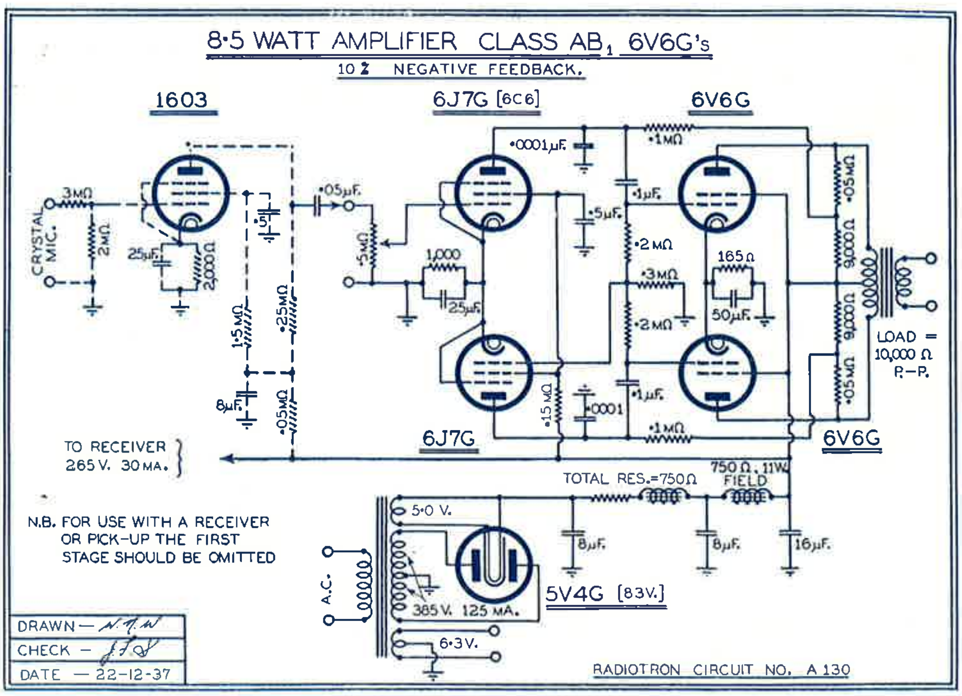

Fig. 4.

RCA APPLICATION NOTE ON A TWO-TERMINAL OSCILLATOR

This Note describes a simple, reliable, two-terminal r-f oscillator whose output voltage is substantially constant over a reasonable range of frequencies. For a given ratio of maximum-to-minimum tuning capacitance, this oscillator may furnish less output voltage than conventional oscillators, but the ease with which adjustments can be made, the uniformity of the output voltage, and the simplicity of coil design, are desirable features.

Three variations of the circuit are shown in Figs. 1, 2, and 3. In these circuits, the output of T_1 feeds the grid of T_2; the output of T_2 feeds the grid of T_1. Thus, the action of T_2 is analogous to that of the tickler in a conventional tickler-feedback circuit. Fig. 1 represents a direct-coupled arrangement. In this circuit, signal and bias for T_2 are obtained directly from T_1. Because of the direct coupling, the internal plate resistance of one valve is connected in series with the internal plate resistance of the other; hence, the B-supply voltage is divided between T_1 and T_2. In the circuit of Fig. 2 and of Fig. 3, capacity coupling between T_1 and T_2 is used; hence, nearly full B-supply voltage is applied to each valve. Fig. 2 differs from Fig. 3 merely in the manner in which B-supply voltage is fed to T_2.

In determining the value of R, tune the oscillator to the low-frequency end of the high-frequency band and adjust the value of R for nearly maximum output. Tune the oscillator to the high-frequency end of that band and

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8.5 WATT 6V6G AMPLIFIER (Continued from Page 100)

the amplifier even under these conditions. The values of plate load resistor, screen dropping resistor and cathode bias resistor in the 1603 are identical to those used for Radiotron 6J7G or 6C6.

In this circuit 10% effective negative feedback is obtained from the resistors of 9,000 and 50,000 ohms arranged as a voltage divider across each half of the output load. The load resistors on the two 6J7G valves have been made 0.1 megohm in place of the more usual 0.25 megohm on account of the lower resistances in the grid circuits of the 6V6G valves. The overall performance curves of the amplifier are given in Figs. 5 and 6, both being taken on a loudspeaker load.

This amplifier is ideally suited to large radio receivers and a receiver current drain of 30 mA. has been allowed for from the power pack. This will cover any normal tuning unit of from three to five valves. A very satisfactory tuner would consist of an R.F. stage (Radiotron 6U7G), converter (6A8G) and I.F. stage (6G8G). If an additional I.F. stage were desired this could be a Radiotron 6U7G arranged immediately following the converter. Radiotron 6U5 or 6G5 Magic Eye might be used to facilitate tuning.

This amplifier might also be used for a small public address amplifier and in this case it could be operated if desired either from A.C. throughout or from 6 volt accumulators for the heaters and from a genemotor for the plate and screen circuits. Due to the low heater current (0.45 A.) of the 6V6G valves the A battery drain is quite light. The amplifier as a whole could be made really portable since no transformers are used in the amplifier.

Radiotron 6L6G's could be applied in a similar way to the 6V6G's in order to obtain a higher output. It is hoped at some later date to describe a larger amplifier using 6L6G's to give an output of about 30 watts.

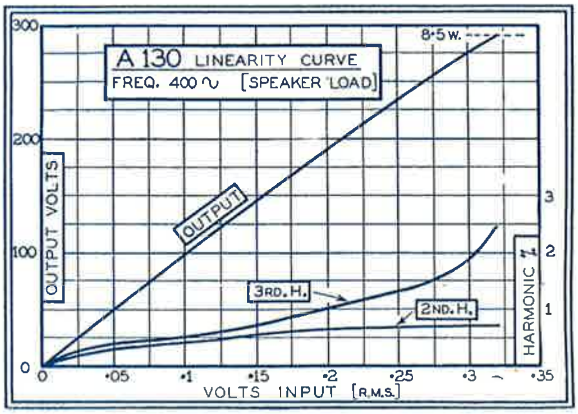


Fig. 5.

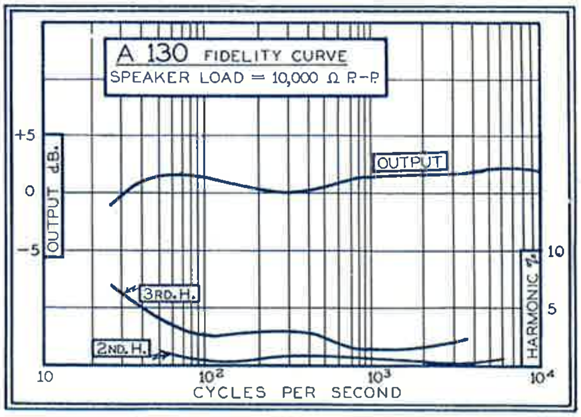


Fig. 6.

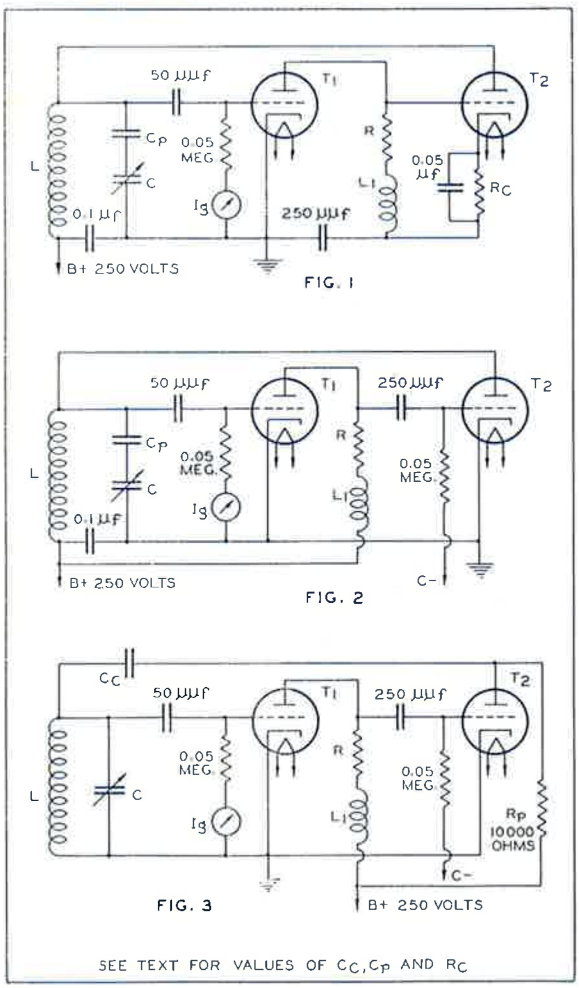
RCA APPLICATION NOTE ON 2-TERMINAL OSCILLATOR

(Continued from page 101)

adjust L_1 for the same output that was obtained at the low-frequency end. Now, measure oscillator amplitude over the tuning range of the wave band; a convenient measure of oscillator amplitude is the value of oscillator grid current I_g. It may be necessary to change these values of R and L_1 in order to obtain a suitable compromise between desired values of tuning range, oscillator amplitude, and uniformity of output. When the valves of R and L_1 are determined in this manner, they need not be changed when the oscillator is switched to any of the lower frequency bands. In these bands, oscillator amplitude is independent of the value of L_1 and is nearly constant over the tuning range of the band.

For a given amplitude of oscillation, the tuning range of this oscillator circuit may be less than that of a conventional feedback circuit because of the high minimum capacitance introduced into the tank circuit by T_2. The shunt-feed circuit of Fig. 3 is suggested as a means of reducing this minimum capacitance. In this circuit, the series combination of C_c and the output capacitance of T_2 is connected across the tank circuit; the entire output capacitance of T_2 is connected across the tank circuit in the series-feed circuit of Fig. 2. A disadvantage of the shunt-feed scheme of Fig. 3 is that the plate voltage of T_2 is reduced by an amount equal to the voltage drop across R_p. Thus, for the same B-supply voltage, increased tuning range is obtained at the expense of reduced oscillator voltage.

TWO-TERMINAL OSCILLATOR CIRCUITS



Typical values of R and L_1 are 200 ohms and 1.5 microhenries, respectively. These values are suggested as guides; final values should be determined by test. The condensers C_p are used to isolate the high voltage from the tuning condenser C; condenser C_p may be a padding condenser when the oscillator tracks with a signal circuit in a superheterodyne receiver. The bias on the grid of T_2 is used to limit the plate current of T_2 to a safe value. This bias is not required under some conditions of operation.

In a typical set-up using the oscillator section of a 6A8 as valve T_1 and a 6J5-G as valve T_2 in the circuit of Fig. 2, a tuning range of 6.4 to 19.7 megacycles (a ratio of 1 : 3.08) was obtained. The oscillator amplitude throughout this range was approximately 100 microamperes. The coil used in this test had a Q of about 100. When the same equipment was used in a shunt-feed circuit of Fig. 3, a tuning range from 6.5 to 20.7 megacycles (a ratio of 1 : 3.18) was obtained. The oscillator grid current became approximately 55 microamperes, because of the comparatively low voltage on the plate of T_2.

No specific valve types are recommended for use with this circuit. Twin-triode types may be used in place of the separate valves shown in Figs. 2 and 3. High output is obtained from valves having high transconductance (g_m); however, such valves usually have high capacitances, which curtail the tuning range. For high output, high g_m in one valve is just as effective as high g_m in the other valve, because of the ring arrangement of the circuit.

The two-terminal feature of this oscillator is an important one for applications which do not require the use of padding condensers. In these applications, the two-terminal oscillator simplifies the switching problem.

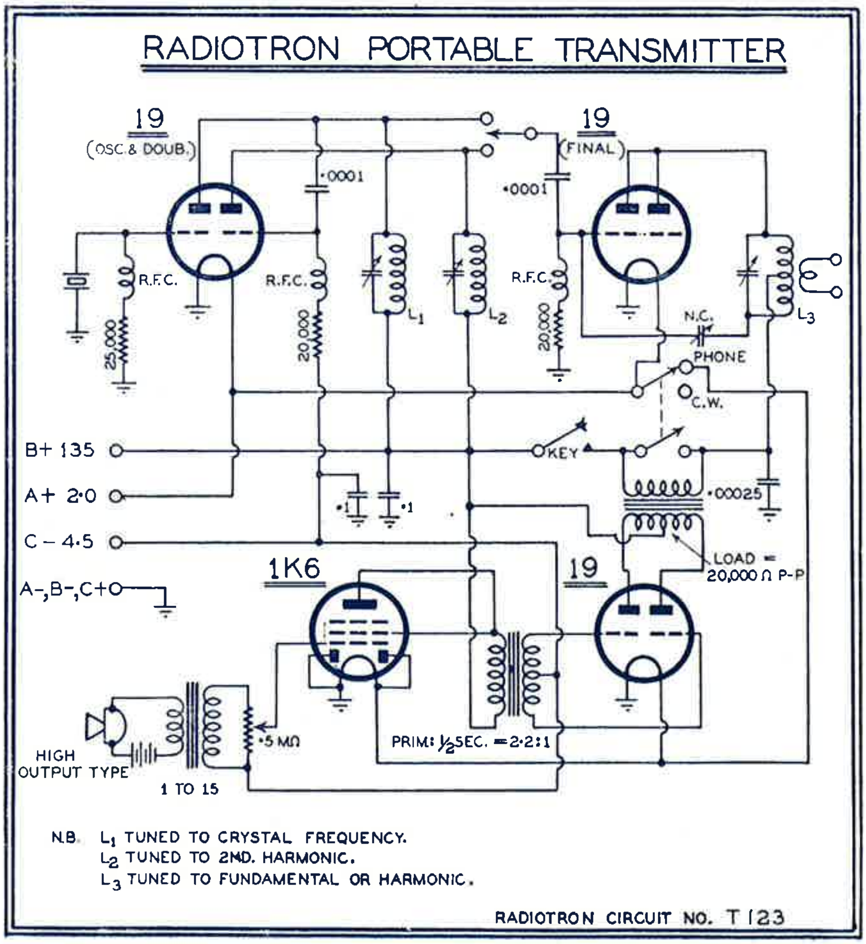
BATTERY OPERATED PORTABLE TRANSMITTER

A simple form of portable transmitter suitable for either 'phone or C.W. operation has been requested by several readers. The design finally adopted incorporates three Radiotrons type 19 and one 1K6. The first 19 is used in two sections as a crystal oscillator and doubler, while the second 19 with both units in parallel is the final stage of the transmitter. This is plate-modulated by the third 19 operating as a class B audio amplifier, which in turn is driven by the 1K6. A high output carbon microphone is used in conjunction with a step-up transformer, having a ratio of 1:15, and by this means there is no difficulty in obtaining sufficient gain to give full modulation. When operation on C.W. is required the modulator may be switched out of circuit and only two valves will then be employed in the transmitter.

The transmitter is capable of radiating either at the fundamental frequency of the crystal or at its second harmonic, depending on the coils which are used for L2 and L3. A "B" battery of 135 volts, an "A" battery consisting of a 2-volt accumulator and a "C" battery of 4.5 volts are required. The whole instrument may be placed into a fairly compact case with a battery either internally arranged or in a separate case for ease in transport. Quite interesting work may be carried out with this small but efficient transmitter and no difficulties should be experienced by anyone who might care to make up such an outfit. Full details are given on the circuit diagram, but the layout is left to the individual designer.

Input to Final Stage (19):—
15 mA. at 135V. = 2 W.
Equivalent load on final stage = 9,000 ohms.
Plate-to-plate load on modulator = 20,000 ohms.
Modulation transformer ratio = 1.5:1 P. to S.

Typical Modulation Transformers:—
Cross section of core — $\frac{3}{4}$ sq. in.
Window area — $\frac{3}{4}$ sq. in.
Primary—7,500 turns 40 S.W.G. enamel.
Secondary — 5,000 turns 40 S.W.G. enamel.
Use "Butt-joint" in core.



NEW RADIOTRON RELEASES

Radiotron 809. New 25 watt Triode

The latest Radiotron release for transmitting purposes is type 809, which is a triode suitable for operation at frequencies up to 60 megacycles with a maximum input of 75 watts and a plate dissipation of 25 watts. The plate voltage may be as high as 750 volts and under these conditions a power output of 55 watts is obtainable with telegraphy, and under reduced ratings for plate modulated class C telephony an output of 38 watts is obtainable with a plate voltage of 600. Radiotron 809 has a very high amplification factor (50), is fitted with a medium 4-pin ceramic base and is arranged so that the plate is brought out to a cap at the top of the bulb. Due to its small dimensions and the ceramic base, the performance on high frequencies is extremely good and full ratings may be used to 60 Mc., 75% ratings to 70 Mc., and 50% ratings to 100 Mc.

Radiotron 809 is particularly interesting at the present time in view of the new limits for experimental transmitters. With plate modulation the maximum plate input is 50 watts, which is the new Australian limit of input. For telegraphy the conditions may be the same as for telephony, using the same voltage of 600 volts, but if higher power is desired the full output of 55 watts may be obtained by increasing the plate voltage to 750 volts.

The filament of the 809 is of the thoriated tungsten type and the voltage should be kept within plus or minus 5% from the rated value.

Due to the high amplification factor, Radiotron 809's are specially suited to class B audio amplification and two of these valves in push-pull are capable of delivering an output of 100 watts using a plate voltage of 750 volts.

A very attractive feature of the Radiotron 809 is the low price at which it is available. The Australian nett price is 25/- and stocks are expected early in February, 1938.

Radiotron 814 — Transmitting Beam Power Tetrode

The Beam Principle has been extended to improve the efficiency of transmitting valves, and the performance obtained with Radiotron 807 has encouraged the development of a larger type on the same principle. Radiotron 814 has a plate dissipation of 50 watts maximum with an output of 130 watts for class C telegraphy and may be operated at maximum ratings on frequencies up to 30 megacycles. Further information will be given in the next issue.

Radiotron 1904 Mercury Vapour Triode POSITIVE GRID CONTROL

Radiotron 1904, which although released some time ago has not previously been described in Radiotronics, is a grid-actuated mercury vapour valve of the hot cathode type designed to provide a local source of A.C. power, whose frequency can be adjusted up to 5,000 cycles per second or higher, and controlled as accurately as desired. The design of the 1904 incorporates a plate, a grid and a highly efficient electron emitting cathode. The rugged electrode assembly is mounted in a dome-top bulb. The heater of the 1904 operates at 5.0 volts 4.85 A. The peak inverse or forward voltage is 1,000 volts maximum. The peak plate current for continuous operation for frequencies above 25 cycles per second is 15 A. maximum, while for frequencies below 25 cycles per second it is 5 A. maximum. For short time operation during which the current peak is limited to 0.1 second, the peak plate current may rise to 25 A. maximum. The average plate current under any condition of operation should not exceed 2.5 A. The grid current should not exceed 1 A. peak or 0.25 A. average. The valve voltage drop is approximately 15 volts and the ambient temperature should be between 20 degrees and 50 degrees Centigrade. The maximum overall dimensions are $7\frac{5}{8}$in. x $2\frac{15}{16}$in. maximum diameter. A medium 4-pin bayonet base is fitted and the plate is brought out to a medium metal cap on the top of the bulb.

The 1904 is particularly suitable in circuits in changing D.C. to A.C. at frequencies up to 5,000 cycles per second. It can also be used for controlling A.C. power circuits and, due to its power handling capability of several hundred watts, it may be used to advantage in numerous ways in the laboratory and in radio applications.

Additional data on Radiotron 1904 are available on request to the Unified Sales-Engineering Service.

Radiotron 884 — Gas Triode

Radiotron 884 is similar in its electrical characteristics to the gas-triode, type 885, except that its heater is rated at 6.3 volts 0.6 ampere, and it is fitted with an octal shell base. Supplies are expected early in February.

(For type 1612 see Page 99)

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